NREL/SNL/BNL PV Reliability Workshops – Lakewood, CO

February 28 – March 2, 2017

The 2017 NREL/SNL/BNL PV Reliability Workshops continue in the tradition of this annual event. Participation requires sharing of a paper—either an oral or poster presentation—by each company at some time during the week.

This year, the event was co-organized with Sandia National Laboratories and Brookhaven National Laboratory, and is divided into two overlapping workshops.

PV Module Reliability Workshop, Feb. 28—March 1, 2017, focuses on PV *modules* with sessions exploring failures that are being seen in PV modules today: cracked cells, light-induced degradation, and other reasons why modules may not perform to their nameplate values, as well as updates from PVQAT.

PV System Reliability Workshop, March 1—2, 2017, focuses on PV *systems* with sessions exploring system reliability, soiling, power electronics, and firefighting safety.

A Joint Session, the afternoon of March 1, 2017, focuses on PV bankability and standards that can help establish bankability.

Both workshops also feature a wide range of poster submissions with a total of almost 100 posters.

Chairs:

Alessandra Colli

Sarah Kurtz

Olga Lavrova

Committee:

Regan Arndt

Markus Beck

Dan Brake

Vivek Gade

William Gambogi

Anastasios Golnas

Dirk Jordan

Geoffrey Kinsey

Michael Koehl

Sumanth Lokanath

Andreas Meisel

Ingrid Repins

Yu-Chen Shen

William Shisler

Mani G. TamizhMani

Tadanori Tanahashi

AGENDA – Tuesday, February 28 - Module Failure Mechanisms and Testing

7:30-8:00	Continental Breakfast
8:00-9:15	**Welcome Session** – Ingrid Repins, NREL and Dana Olson, DOE (Chairs) **8:00** – Welcome to the PV Module Reliability Workshop – Sarah Kurtz, NREL, and Charlie Gay, DOE **8:15** – Changes in observed PV failure & degradation modes – Dirk Jordan (101), NREL **8:45** – Observations of new problems with PV modules – Eric Daniels (102), Suncycle USA
9:15-10:00	**Poster Session I** *(see Poster Agenda)* with Coffee
10:00-11:40	**10:00** – Electrochemical mechanisms of leakage-current-induced delamination and corrosion – Yu-Chen Shen (103), Jichao Li, Constellium Automotive USA, Peter Hacke, NREL, Mike Kempe, NREL, Charlie Hasselbrink, SunPower, and George Mseis, Total **10:30** – Durability evaluation of field-aged PV modules from diverse climates: causes of series resistance increase – Mani G. TamizhMani (104), ASU **11:00** – Discussion: *What other new failure mechanisms are being observed? How does the observation of new failures affect our research agendas and test plans? How do we develop tests, standards, and lifetime models to address these new failure mechanisms? Do we need a new twist test?*
11:40-12:40	Lunch – Poster viewing/discussion encouraged
12:40-14:30	**Cracked Cells** – Alessandra Colli, BNL, Andreas Meisel, SolarCity, and Eric Daniels, SunCycle (Chairs) **12:40** – Ultraviolet fluorescence method to detect cell cracks and safety issues of cell cracks – Marc Koentges (105), ISFH **13:00** – Field observations of cracked cells – Jim Rand (106), Core Energy Works **13:15** – Look while you load: Electroluminescence and IV testing of solar panels under mechanical load Andrew Gabor (107), BrightSpot Automation **13:30** – Metrology for cracks in modules – Klaus Attenkofer (108), NSLSII, BNL **13:45** – Discussion: Panel Participants: Marc Koentges, Jim Rand, Andrew Gabor, Klaus Attenkofer *"What does it mean to have cracks? (What do we need to do? Can we live with the power loss and the safety risk? Are there thresholds to respect for electric or temperature variables of the module? Are there differences in impact for different cell types?) "What can we do to reduce problems with cracked cells?" "Should we be developing a new standard to better understand the effects of cracks combined with mechanical strain?" "Do wind, snow, or tracker stow position contribute to cell cracking?"*
14:30-15:15	**Poster Session II** *(see Poster Agenda)* with Coffee
15:15-17:00	**LID and Other Questions about Nameplate Ratings** – Bill Shisler, NRG Energy and Andreas Meisel, SolarCity (chairs) **15:30** – Effects of nameplate assignment – how important is it in determining energy delivered relative to the effects of variable operating conditions? – Markus Schweiger (109). TUV Rheinland Energy GmbH **15:50** – Module Tester Spectral Classification: Focus on industrial silicon modules – Ron Sinton (110), Harrison Wilterdink, and Wes Dobson, Sinton Instruments **16:10** – LID effects and their deactivation in PERC type solar panels – Max Koentopp (111), Hanwha Q-cells GmbH **16:30** – Discussion: *What are the most common reasons why a module may not deliver the power indicated by the nameplate? Is LID in PERC a problem? Will regeneration be stable? What are the differences between mono and multi? How do these problems compare with effects in thin-film and other silicon cells? How can we reduce the uncertainty of nameplate ratings without increasing cost?*
17:00	Adjourn – Poster viewing/discussion encouraged

POSTER SESSIONS I & II

TUESDAY MORNING, February 28, 2017
POSTER SESSION I

1. **Teresa Barnes (NREL),** "DuraMAT overview"
7. **Scott A. Roberts (Sandia National Laboratories), James Y. Hartley, Laura T. Schelhas, Nick Bosco, Mark Van Benthem,** "Thermal-mechanical-electrical model for PV module-level failure mechanisms - DuraMat core capability – predictive simulation"
13. **Kurt Barth (Next Generation PV Center at Colorado State University),** "Opportunities to improve module reliably and reduce cost (DuraMAT)"
19. **Peter Hacke (NREL), Olga Lavrova,** "Module testing in DuraMAT"
25. **Bruce King (Sandia National Laboratories),** "DuraMAT capability 5: field deployment"
31. **Mohammad Aminul Islam (NAIST), Yasuaki Ishikawa, Sadao Sakamoto, Hidenari Nakahama, Atsushi Masuda,** "Causes of the most frequent degradation mode of crystalline silicon PV modules"
37. **S.K. Tippabhotla (XPV), W.J.R. Song, A.A.O. Tay, A.S. Budiman,** Role of encapsulants on the process induced residual stress in the crystalline silicon solar cell modules using 2D finite element simulations
43. **Tadanori Tanahashi (AIST), Norihiko Sakamoto, Hajime Shibata, and Atsushi Masuda** "Cause of current-collection failure observed in Isc-reduction phase of PV cells and modules exposed to acetic acid"
49. **Josh Gallon (Tau Science),** "Module quantum efficiency mapping techniques"
55. **Steven P. Harvey (NREL), J. Moseley, A. Stokes, A. Norman, B. Gorman, P. Hacke, S. Johnston, M. Al-Jassim,** "Investigating PID shunting in polycrystalline silicon modules via multi-scale, multi-technique characterization"
61. **Christopher P. Thompson (IEC, University of Delaware), Steven Hegedus,** "Characterization of accelerated degradation modes: applying light and voltage bias during damp-heat exposure"
67. **H. Tomita (Solar Frontier), D. Schmitz, S. Tokuda, K. Sakurai, K. Ogawa, A. Masuda,** "Effect of light irradiation on PID testing of CIGS PV modules"
73. **Lorelle Mansfield (NREL), Peter Hacke, Miguel A. Contreras, Ingrid Repins,** "Accelerated PID testing on packaged CIGS devices"
79. **Elsa Kam-Lum (Total New Energies), Amjad Deyine**, "Presence of sulfur in screen-printed silver conductor of cells found to result in Ag depletion in 85%RH/85°C biased DH at +1kV"
85. **D. Vasileska (Arizona State University), A. Shaik, D. Guo, C. Ringhofer, D. Brinkman, D. Krasikov, I. Sankin,** "Unified numerical solver for modeling metastability and reliability of CdTe solar cells"
91. **Pradyumna Muralidharan (ASU), "**Multiscale modeling of silicon heterojunction solar cells"
97. **L. Pratt (CFV), C. Schmid, and C. Stark,** "Multiple failure modes from fielded silicon modules"

TUESDAY AFTERNOON, February 28, 2017
POSTER SESSION II

2. **Nick Bosco (NREL),** "Quantifying adhesion: the width-tapered cantilever beam demonstrated for PV modules and materials"
8. **Martin Sander (Total Gas, Renewables & Power), G. Mseis, L. Hudanski**, "Determination of mechanical stress in encapsulated solar cells by combination of finite element analysis and strain gage measurements"
14. **W. Luo (SERIS), J. Chai, Y. Khoo, Y. Wang,** "Potential-induced degradation of n-type bifacial modules"
20. **S. Uredat, E. Malguth, and V. Blank (LayTec in-line GmbH),** "Probe indentation method for fast and non-destructive determination of the cross-linking degree of EVA encapsulants"
26. **L. Pratt (CFV), J. Crimmins, K. Lee,** "Thermal cycling of Si PV modules at high ramp rate and high temp"
32. **H. Kim (Purdue),** "Microstructure simulation of polycrystalline thin films"
38. **A. Budiman (SUTD), Sasi K. Tippabhotla, I. Radchenko, and N. Tamura**, "Probing stress evolution in crystalline silicon cells using synchrotron x-ray micro-diffraction – enabling thin silicon solar cell technologies for next-generation solar PV systems"
44. **Matevž Bokalič, (University of Ljubljana), Rok Kimovec, James R. Sites, Marko Topič,** "Phantom inhomogeneities in CdTe PV devices as seen by electroluminescence"
50. **Cordula Schmid (Fraunhofer CSE),** "Glass-less, frame-less lightweight c-Si module durability and robustness testing: a survey"
56. **Jiadong Qian (ANU), Andrew Thompson, Andrew Blakers,** "A method to simulate the hotspot temperature of partial shaded PV modules"
62. **S. Bhaduri, Shashwata Chattopadhyay (IIT Bombay), R. Dubey, S. Zachariah, V. Kuthanazhi, C. Singh Solanki, A. Kottantharayil, Brij M. Arora, K.L. Narasimhan, J. Vasi**, "Correlating IR thermography with electrical degradation of modules inspected in all-India survey of photovoltaic module reliability 2016"
68. **Jim Sorensen (First Solar),** "Identification, testing, & differentiation in crystalline Si module cell cracking"
74. **Tim Peshek (NASA), Anna Maria Pal, Jeremiah McNatt, Richard Pappa,** "Martian 'terrestrial' PV: design considerations for a long-lived PV installation on the Red Planet"
80. **Ina T. Martin (Case Western Reserve), Lorelle M. Mansfield, Rachael Matthews, Emily B. Pentzer, Roger H. French, Timothy J. Peshek,** "Modification of ZnO:Al surfaces for improved lifetime performance"
86. **Eric Schneller (FSEC), A.Gabor, J. Lincoln, R. Janoch, A. Anselmo, J. Walters, H. Seigneur,** "Advanced mechanical stress testing using the LoadSpot"
92. **Saurabh Chatterjee (Panasonic),** "Snail trail impact on solar PV module performance"
98. **Julien Avenet (NIST), J. Kim, Y. Lyu, X. Gu,** Photodegradation of PET-based films and its implication to backsheet application

AGENDA – Wednesday, March 1 - PVQAT Updates and Discussions; Bankability

7:30-8:00	Continental Breakfast
8:00-9:10	**PVQAT Updates and Technical Discussions** Nancy Phillips, DuPont and Harrison Wilterdink, Sinton Instruments (Chairs) **8:00** – PVQAT TG1 update: Status and implementation of IEC 62941, Masaaki Yamamichi (112), AIST, Govind Ramu, SunPower, Sarah Kurtz, NREL, George Kelly, Sunset Technology **8:10** – Task Group 10: Update on issues related to connectors, Sumanth Lokanath (113), First Solar **8:25** – PVQAT TG4 (Diodes): Climate and mounting specific accelerated test development, Vivek Gade (114), Jabil **8:40** – Discussion: *Are diode failures being observed at a higher rate in hot climates?* **8:50** – SAYURI Workshop report – Tadanori Tanahashi (115), AIST **9:00** – SOPHIA Workshop report – Bengt Jaeckel (116), UL
9:10-9:55	**Poster Session III** *(see Poster Agenda)* with Coffee
9:55-12:00	**PVQAT Updates and Technical Discussions Continued** Tim Silverman, NREL and Keiichiro Sakurai, AIST (Chairs) **9:55** – PVQAT TG3: proposed PID pass-fail requirement for amendment to IEC 61215, other TG3 status and combined stress testing Peter Hacke (117), NREL **10:15** – Discussion: *What data are available to define how to test for PID in thin-film modules? For which situations do we expect to use combined-stress testing* **10:25** – PVQAT TG5: introduction and status of weathering standards development, David Miller (118), NREL; Current questions and issues, Nancy Phillips, DuPont; Overview of active research efforts, David Miller; Insights from recent studies, Xiaohong Gu, NIST; Past, present and developing standards in the industry, David Miller; The future of weathering tests, Sean Fowler, Q-lab **10:55** – Discussion: *What should be the pass/fail criteria for weathering tests? Where should those criteria be applied? What method or test sequences are not addressed in the PV standards that need to be considered?* **11:10** – PVQAT TG2: proposal for extended thermal cycling, Nick Bosco (119), NREL **11:25** – PVQAT climate specific: proposal for testing for high-temperature operation, John Wohlgemuth (120), PowerMark **11:40** – Discussion: *Is this the right approach? What concerns are there about the proposed thermal cycling test protocol? Would it be accepted as a standard approach for an extended durability test protocol*
12:00-13:00	**Lunch** – Poster viewing/discussion encouraged
13:00-14:30	**Final Session of PV Module Reliability Workshop; First Session of PV System Reliability Workshop (Joint Session)** **Bankability – What does an investor want?** Yu-Chen Shen and Sarah Kurtz, NREL (Chairs) **13:00** – Welcome to joint session of Module and System Workshops, Geoffrey Kinsey, DOE **13:10** – Scientific basis for using a durability protocol to gain confidence in long-term performance of modules – Jon Previtali (121), Wells Fargo **13:30** – Proposal of a quality assurance test protocol to unify reliability testing, Clifton Rondeau (122), CSA **13:50** – Panel Discussion: Panelists: Jon Previtali, Wells Fargo, Edward Hsi, Ralph Romero, Black & Veatch, Clifton Rondeau, CSA, Jim Crimmins, CFV, Jim Sorensen, First Solar *What information do investors require for different levels of confidence in PV modules? Is CSA's proposed Test Protocol what the investors/customers/manufacturers want?*
14:30-15:15	**Poster Session IV** *(see Poster Agenda)* with Coffee
15:15-17:00	**Bankability – Are the standards in development addressing the investors' questions?** **15:15** – What does an independent engineer look for in a PV plant and what enhanced-reliability data would motivate paying more? – Ray Hudson (123), DNV GL **15:45** – IECRE approach to providing confidence at the system level, George Kelly (124), IECRE **16:15** – Panel Discussion: Ray Hudson, DNV GL, George Kelly, IECRE, Jon Previtali, Wells Fargo, Ralph Romero, Black & Veatch, Sumanth Lokanath, First Solar, Mark Preston, Array Technologies *Is the IECRE effort headed in the right direction including all pieces: quality, performance, oversight, and consistent application? What fraction of bankability comes from technical vs financial/business considerations? What are factors beyond the upfront cost that are most important in considering the economics of the total cost of the project (over the life of the project)? How to quantify degradation?*
17:00	**Adjourn** – Poster viewing/discussion encouraged

POSTER SESSIONS III & IV

WEDNESDAY MORNING, March 1, 2017
POSTER SESSION III

3. **Steve Johnston (NREL),** "Multi-Scale Imaging and Microscopy to Characterize Module Degradation Mehanisms"

9. **John Wohlgemuth (PowerMark), Alex Mikonowicz**, "PV standards activities of IEC"

15. **B. Jaeckel (UL), R. Gottschalg J. Arp,** "Measurement uncertainty: a new holistic approach to reduce the pain of uncertainty!"

21. **Mark Alessandro (Avery Dennison), Emre Unsal, Doug Vermillion,** "Comparison of weathering test chamber light source spectra, and summary update on developing metal halide light source testing standards"

27. **Robert Jan van Vugt (Eternal Sun),** "Combined stress testing with in-situ performance measurement"

33. **C. Castaneda, S. Chattopadhyay, J. Oh, Sai Tatapudi (Arizona State University), Mani G. TamizhMani, H. Hu**, "Quantitative correlation between processed EL images and performance of PV modules"

39. **Brian Habersberger (Dow Chemical), Lisa Madenjian**, "Polyolefins: durable materials for improving lifetime performance of PV modules"

45. **Jae Hyun Kim (NIST), Samantha Weaver, Christopher M. Stafford, Yadong Lyu, Andrew Fairbrother, Julien Avenet, David C. Miller, Xiaohong Gu,** "Spectroscopic and mechanical characterizations for degradation behaviors of EVA encapsulants in glass/EVA/glass system"

51. **Felix Garcia-Rosillo, M. Carmen Alonso-Garcia (CIEMAT),** "Evaluation of color changes in PV modules using reflectance measurements"

57. **Chuanxiao Xiao (NREL), Steve Johnston, Peter Hacke, J. Wohlgemuth, M. Al-Jassim,** "Failure analysis to identify thermal runaway of bypass diodes in fielded modules"

63. **W. Gambogi (DuPont), T. Felder, B.L Yu, S. MacMaster, K. Stika, K. Roy Choudhury, and T. John Trout,** "Module accelerated sequential stress testing and comparison to field performance"

69. **Kaushik Roy Choudhury (E.I. DuPont de Nemours), William Gambogi, Thomas Felder, Alexander Bradley, Steven MacMaster, Lucie Garreau-Iles, Hongjie Hu, T.-John Trout,** "Recent failures of backsheets in fielded PV modules and their relation to material degradation"

75. **Michael D. Kempe (NREL), David C. Miller, Allen Zielnik, Daniel Montiel-Chicharro, Jiang Zhu, Ralph Gottschalg,** "Survey of mechanical durability of PV backsheets"

81. **Jessica Rosenthal (Soliculture), G. Alers, I. Anderson,** "Development of a single-layer clear PV backsheet"

87. **Andrew Fairbrother (NIST), J. Avenet, Y. Liu, M. Boyd, S. Julien, K. Wan, L. Ji, K. Boyce, S. Merzlic, A. Lefebvre, G. O'Brien, Y. Wang, L. Bruckman, R. French, M. Kempe, B. Dougherty, X. Gu,** "PV module backsheet degradation and differential exposure conditions due to site design"

93. **Eric J. Schneller (FSEC), David C. Miller, Onkar Shinde, Sai Tatapudi, Govindasamy Tamizhmani, Neelkanth Dhere**, "Encapsulation performance after three years in the field: a comparison of hot/humid and hot/dry climates"

96. **Yadong Lyu (NIST), J. H. Kim, X. Gu**, "Fluorescence imaging on the cross-section of degraded PV laminates"

WEDNESDAY AFTERNOON, March 1, 2017
POSTER SESSION IV

4. **Kyung Soo Kim (Korea Institute of Energy Research)** "High sun irradiance testing for understanding material lifetime expectation of PV modules"

10. **Kyungsoo Lee (Korea Polytechnic University**), "Overview of PV project design qualification certificate of IECRE OD-403"

16. **Rounak A. Kharait (Leidos), John W. Graff, Larry McClung, Alex Schneider, Phil Stiles,** "Impact of degradation rates on solar PV project financials"

22. **Jim Joseph John (Dubai Electricity and Water Authority- DEWA), Ammar Elnosh, Alya Bin Took, Marco Stefancich, Pedro Banda**, "Evaluation of various PV module technologies in desert conditions using weather-corrected performance ratio"

28. **John A. Tsanakas (Institute for Energy Technology), Eric Pilat, Long D. Ha, Franck Al Shakarchi,** "Early reliability issues and symptoms evaluated in four large PV plants in southern France"

34. **Nicholas Riedel (Denmark's Technical University),** "Toward a drone-based EL and PL inspection tool for PV power plants (DronEL)"

40. **Frederic Dross, J. Watts, J. Mehdbray, F. Ramirez, D. Morbitzer, J. Castro, J. Duncan, S. Montminy,** "Statistics for evaluation of > 12,000 modules"

46. **Emily Hardy (EDP Renewables North America),** "PV energy losses in snowy conditions"

52. **Mark Reusser (ICF), Heidi Marie Larson**, "Understanding the performance of distributed solar assets"

58. **Laura Schelhas (SLAC), Michael Toney,** "Operando X-ray diffraction for characterization of PV materials"

64. **Vincent Weeda (Fortum),** "Demonstrating the need for Fortum's QA program"

70. **Machado Neto, L.V.B. and A.S.A.C. Diniz (Pontifical Catholic University of Minas Gerais)** "Parameters estimation and thermographic analysis for evaluation of degradation and reliability of PV generators with 19 years of use in Amazon Forest"

76. **Frederic Dross (DNV GL PVEL), Jenya Meydbray, John Watts,** "What does the data of years of accelerated testing tell us?"

82. **Gregory O'Brien (Arkema), Amy Lefebvre, Bryan Douglas**, "Five-year outdoor and accelerated weathering of Kynar fluoropolymers - a case for better zip ties"

88. **Vivek Gade (Jabil Solar and Environmental Test Center), Jared Opalewski, Narendra Shiradkar, Shesh Vaishnav**, "Accelerating testing of photovoltaic modules in extreme climates"

94. **Rob Andrews (Heliolytics), Kristine Sinclair**, "Summary of DC losses observed using aerial infrared inspection across >1.6 GW"

AGENDA – Thursday, March 2 – System Reliability, Soiling Power Electronics, Fire

7:30-8:00	Continental Breakfast
8:00-9:50	**System Reliability** Olga Lavrova, Sandia National Laboratories and Geoffrey Kinsey, DOE (Chairs) **8:00** – Welcome, Olga Lavrova **8:10** – Central inverter cost of ownership & event analysis – Sumanth Lokanath (125), First Solar **8:30** – PV power electronic product reliability testing program – Rui Li (126), Celestica, Blake Harper, Julian Emmanuel, Shane Kennedy, Yinni Cao, Dan Henes, J. Natstasi **8:50** – Improved performance modeling that reflects component reliability metrics – Geoffrey Klise (127), Sandia National Laboratories **9:10** – O&M cost modeling and cost reduction – Andy Walker (128), NREL **9:30** – Discussion *What are the most significant issues for PV plants today? Are there new research directions we should be heading?*
9:50-10:30	**Poster Session V** *(see Poster Agenda)* with Coffee
10:15-12:00	**Soiling** Mowafak Al-Jassim, NREL and Leo Micheli, CSM (Chairs) **10:30** – A commercial system perspective on mitigating PV soiling losses – Sanjay Shrestha (129), SOLV **10:45** – Progress towards mapping out PV soiling losses in the US – Matthew Muller (130), NREL **11:00** – Overview of Sandia's soiling program: experimental methods and framework for a quantitative soiling model – Bruce King (131), Sandia National Laboratories **11:15** – Adhesion mechanisms for soiling on PV glass – Lin Simpson (132), NREL **11:30** – Discussion: *What progress is needed to help understand and/or reduce losses from soiling? What soiling standards are needed?*
12:00-13:00	**Lunch** – Poster viewing/discussion encouraged
13:00-14:45	**Power Electronics** Mani G. TamizhMani, ASU and Peter Hacke, NREL (Chairs) **13:00** – Reliability assessment of MLPEs under humid environment using physics-of-failure approach." – Arvind Vasan (133), Empower Micro Systems **13:15** – Reliability assessment in PV inverters, Vicente Salas (134), University of Madrid **13:30** – Electromagnetic interference (EMI) & its role in inverter reliability" – Regan Arndt (135), Empower Micro Systems **13:45** – IEC 62093: proposed approach to testing inverters" – Paul Parker (136), SunPower and Paul Sochor, TUV **14:15** – Discussion: Panelists (in addition to speakers) Jonathan Pantano, NextEra, Jack Flicker, Sandia National Laboratories, Sumanth Lokanath, First Solar *What are critical failures being observed in power electronics and how can we decrease the number of these? Are the planned qualification (IEC 62093), safety (IEC 62109), and quality management (NWIP) standards appropriate and adequate? Do we need to be doing more on EMC functional safety and reliability?*
14:45-15:30	**Poster Session VI** *(see Poster Agenda)* with Coffee
15:30-17:00	**Rapid shutdown and enhancing firefighting safety** Greg Ball, SolarCity, and Chris Deline, NREL (Chairs) **15:30** – NEC 2017 requirements related to rapid shutdown and firefighters' safety" – Bill Brooks (137), Brooks Engineering **16:00** – Current UL proposal for meeting NEC 2017 third option and future steps for 2019" – Tim Zgonena (138), UL **16:30** – Panel discussion: Tim Zgonena, UL, Olga Lavrova, Sandia National Laboratories, Bill Brooks, Brooks Engineering *What are the technical challenges of rapid shutdown (and module electronics, in general)? What are the technical expectations for what "rapid shutdown" will mean? Do we agree on the safety limits of the voltage, power, and approach boundary? Are options for addressing the new standards available?*
17:00	**Adjourn** – All posters removed

POSTER SESSIONS V & VI

THURSDAY MORNING, March 2, 2017
POSTER SESSION V

5. **Michael Bolen (EPRI)** "Corrosion of buried steel racking at utility-scale PV plants"

11. **Bill Stueve (Atonometrics)** "Modeling GHI, DNI, & DHI from POA irradiance using GTIDIRINT"

17. **Michael Deceglie (NREL), Leonardo Micheli, Matthew Muller, Sarah Kurtz,** "Calculating annual soiling loss from PV production data"

23. **Ajay Singh and Matthew Perry (Campbell Scientific)** "Effect of multi-parameter filtering on soiling loss index"

29. **Josefine Selj (Institute for Energy Technology), M. Øgaard, J. A. Tsanakas, E. S. Marstein, S. E. Foss,** "The effect of soiling on the performance of PV modules in a semi-arid area in South Africa"

35. **Leonardo Micheli (NREL), M. Deceglie, M. Muller,** "On seasonal soiling trends and their predictability"

41. **Larry Kazmerski (University of Colorado, NREL), A. Sonia A.C. Diniz, C. Brasil Maia, Marcelo Machado Viana, Suellen C. Silva Costa, P. Paiva Brito, C. Dias Campos, S. de Morais Hanriot, D. Senna Costa, E. Marc, F. Costa, L. R. de Oliveira Cruz, M. G. TamizhMani** "PV module surface soiling studies in Brasil: Program and research progress"

47. **Thomas Griffin (SOL Systems), "**Using solar production data to calculate average soiling rates and characterize the effects of specific weather events"

53. **R. Fleming (Wattglass), B.M. Freiburger, Corey S. Thompson, S. C. Pop,** Development of a durable high-performance antireflective glass coating with resistance to particulate soiling"

59. **Nicoleta Voicu (DSM), C. Carcouet, P. Tummers, I. Bennett, N. Sicchieri, H. Schoot,** "Anti-soiling coatings for PV applications"

65. **Ashwini Pavgi, Jaewon Oh (Arizona State Univ.), J. Kuitche, S. Tatapudi, M. G. TamizhMani**, "Thermal non-uniformity in PV modules and plants: influence on performance parameters"

71. **Liviu Stoicescu (Solarzentrum Suttgart), Michael Reuter,** "DaySy evaluates PID losses in the field"

77. **Junpei Irikawa (Eco Solutions), Akimichi Maekawa, Hiroshi Kanno, Hiroshi Inoue, Mikio Taguchi, Shingo Okamoto,** "Inspection methods of outdoor solar system by using UV irradiation"

83. **Jeffrey Webber (Cypress), Evan Riley,** "Mismatch loss reduction in PV arrays as a result of sorting PV modules by max-power parameters"

89. **Mark A. Preston (Array Technologies), John Williamson,** "Tracker lifetime cost"

95. **Regan Arndt (Empower),** "Electromagnetic interference and its role in inverter reliability"

THURSDAY AFTERNOON, March 2, 2017
POSTER SESSION VI

6. **Janine Freeman (NREL),** "A stochastic model for PV system reliability and performance (PVRPM)"

12. **Yongheng Yang (Aalborg University), Ariya Sangwongwanich, Frede Blaabjerg,** "Design for reliability of power electronics for PV systems"

18. **Naveen Goswamy and Yves Poissant (CanmetENERGY),** "Degradation studies of a photovoltaic system operating in the Canadian Arctic for 21 years"

24. **Andreas Livera, Marios Theristis *(University of Cyprus)*, George Makrides, George E. Georghiou,** "Failure detection and classification algorithms for grid-connected PV systems"

30. **Peter Hacke (NREL), Miguel Rodriguez, Ingrid Repins,** "Testing of a combined stress cycle on module level power electronics"

36. **Jack Flicker (Sandia National Laboratories),** "Reliability of module level power electronics"

42. **Sarah Kurtz (NREL), Govind Ramu, Robert Cornell, Masaaki Yamamichi, George Kelly, John Wohlgemuth** "Bringing PV system quality standards to the next level"

48. **Peijun Shen (Huawei Technologies), Xin Gu, Juan Hu, Xianmiao Zhang,** "Online I-V scanning and intelligent diagnosis on the faults of the solar panels of the operating plants"

54. **Adam Shinn (kWh Analytics),** "RdTools: open-source toolbox for degradation analysis"

60. **Yu Wang (Case Western Reserve Univ.), Sebastien Merzlic, Andrew Fairbrother, Lucas Fridman, Scott Julien, Amy Lefebvre, Xiaohong Gu, Liang Ji, Ken Boyce, Kai-tak Wan, Roger French, Laura Bruckman,** "Stress/response degradation model of photovoltaic modules exposed in different climatic zones"

66. **Andreas Livera, Alexander Phinikarides, Marios Theristis (University of Cyprus), George Makrides, George E. Georghiou,** "Impact of missing data on the estimation of photovoltaic degradation rate"

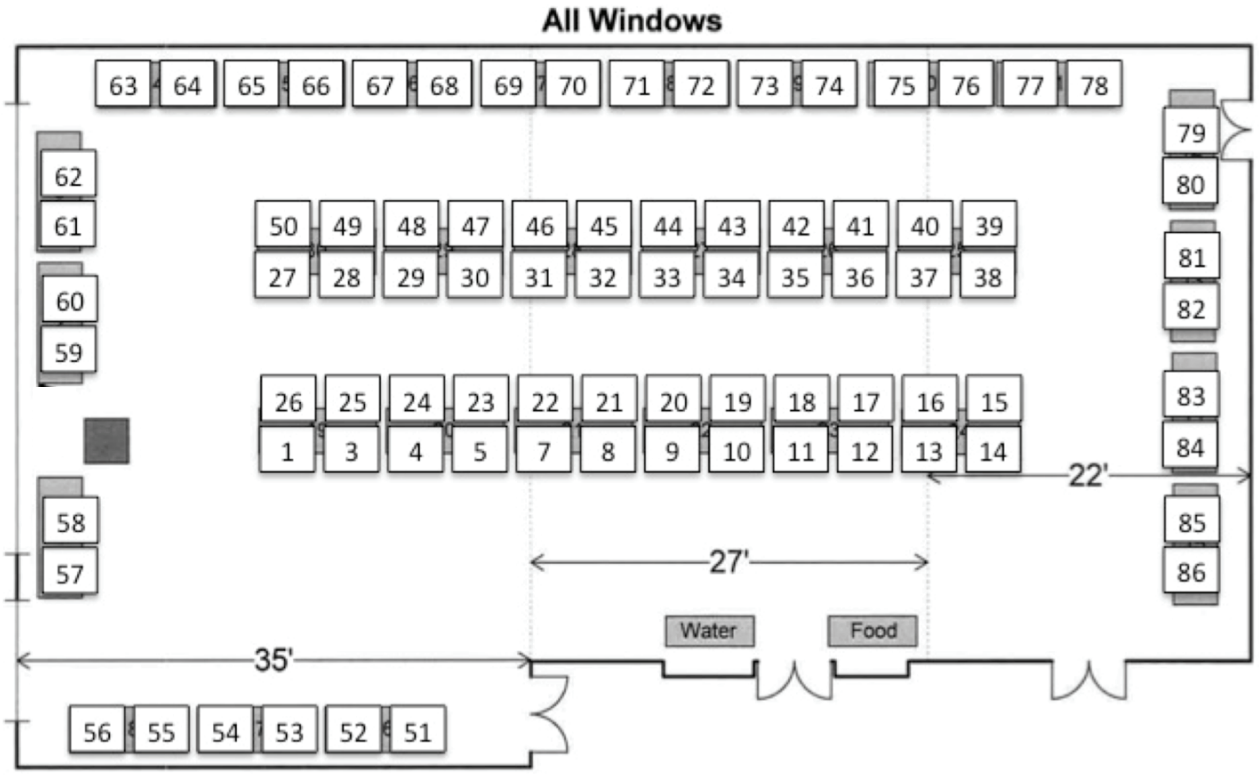
72. **Yang Hu, Alan Curran (Case Western Reserve University), Rojiar Haddadian, Timothy J. Peshek, Roger H. French,** "Month-by-month analysis of the power change rate of real-world, outdoor, photovoltaic systems across multiple climate zones"

78. **Y. Fang, (ASU) D. Guo, S. M. Goodnick and D. Vasileska,** "Drift-diffusion InGaN/GaN solar cell simulator with optical management"

84. **Birinchi Bora (NISE), O.S. Sastry, B. Prosad,** "Degradation of different PV module technologies under field conditions in India"

90. **K. Sinclair (Heliolytics), M. Sinclair, D. Jordan,** "Visual inspection guide for sub-standard PV Si modules"

POSTER LAYOUT – CITY LIGHTS BALLROOM



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